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A STUDY OF GRADE ONE CHILDREN'S CONCEPTS OF LINEAR MEASUREMENT

by

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A THESIS

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ABSTRACT

The purpose of this study was to determine to what extent some of the more important aspects of the basic concepts of linear measurement had developed in grade one children after they had received formal instruction in a particular arithmetic program for nine months. The study concerned itself with the following aspects of measurement: 1) reconstructing relations of distance, 2) the conservation of measurement when the length of lines and the coincidence of their extremities is considered, 3) the conservation of length with a change of position, 4) the conservation of length with a distortion of shape, 5) measurement of length, and 6) subdividing a straight line and selecting an appropriate unit of linear measurement. In addition the study took into consideration the simultaneous effect of sex, mental ability, socio-economic status and arithmetic program on the development of the concepts of linear measurement in young children.

A test was designed and was constructed. It consisted of six subtests, each designed to measure a particular concept, and administered individually to a group of grade one children attending the city of Edmonton Public Schools in June, 1964. The principal sample consisted of one hundred twenty children, sixty who had been exposed to the Numbers

We Need series by Brownell and Weaver and sixty who had received arithmetic instruction from the *Seeing Through Arithmetic* series by Hartung et al. A subsidiary sample of twenty children was also selected from a group that had been instructed by the Cuisenaire method.

The responses of the children were scored and the results thus collected were statistically analysed. A four-way analysis of variance was used to treat the data resulting from the central problem. t tests of significance were used in the treatment of the data resulting from the auxiliary sample.

On the basis of the findings of this study the following conclusions were reached.

1. Differences in sex and environment do not contribute significantly to the development of the concepts of linear measurement in young children.
2. Children with higher mental ability were clearly superior in their understanding of linear measurement although no child had achieved complete mastery of the relevant concepts.
3. Differences in the treatment of linear measurement in the three arithmetic programs considered did not contribute significantly to the development of measurement concepts in young children.
4. The verbalization of measurement terms or the identification of measuring instruments is no assurance that the young

child understands the underlying concepts.

Some implications for educational practice are presented together with some suggestions for further research.

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CHAPTER I

THE PROBLEM AND DEFINITION OF TERMS USED

The growing concern with the problem of measurement in the elementary school has resulted in a shift of emphasis in some current arithmetic programs from a memorization of long tables of measures of common usage to a systematic organization of meaningful experiences designed to awaken in young children the need for standard units of measurement and subsequent competence in the manipulation of these units in practical situations. These newer programs are based on the assumption that children who begin school have varied backgrounds and experience. Starting with very basic ideas of measurement the comparison of common objects to ensure familiarity with the ideas expressed by the words many and few, big and small, tall and short, wide and narrow is introduced in these programs. These concepts and skills are presented in a sequential development. Formal work is undertaken only after these basic concepts have been estaolished.

This approach is an attempt to incorporate in the learning experience recent findings of psychological and educational research.

Purpose of the Study

The purpose of this study is to determine to what

extent some of the more important aspects of the basic concepts of linear measurement have developed in grade one children after they had been exposed to formal instruction including measurement, for nine months. These aspects of measurement with which this study is concerned are: reconstructing relations of distance, the conservation of length when the length of lines and the coincidence of their extremities is considered, the conservation of length with a change of position, the conservation of length with a distortion of shape, the measurement of length, and subdividing a straight line and selecting an appropriate unit of linear measurement.

I. THE PROBLEM

It can not be assumed that because a child can go through the process called measurement he understands measurement. A child may apply a ruler to a segment and still not understand the significance of the process. The mastery of a particular concept is a process which proceeds continuously from one level of development to another. The child acquires new ideas based on skills that he has already mastered. Therefore an understanding of the concepts of linear measurement that young children have may enable teachers to adapt their methods and to plan and guide appropriate readiness activities that are based on a continuity

of meaningful learning experiences. A knowledge of the developmental character of this concept may point to the futility of having children memorize long tables of measures of common usage or of teaching measurement procedures prior to the child's ability to cope with the relevant concept.

II. LIMITATIONS OF THE STUDY

This study will be confined to some of the aspects that are considered fundamental to the development of concepts of linear measurement in grade one children. It will also be restricted to those children who were in attendance in grade one classes of the Edmonton Public Schools in June, 1964.

The sample selected is assumed to be representative of this school system's grade one classes.

III. DEFINITIONS OF TERMS

Conservation is the invariance of a given quantity, that is, a given quantity remains the same regardless of the arrangement or rearrangement of its parts.

Concept is a system of learned responses the purpose of which is to organize and interpret the data by sense perception.[1]

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[1]Robert Thomson, The Psychology of Thinking (Baltimore, Penguin Books Inc., 1963) p. 65.

Haptic perception is the manner in which a child recognizes various objects by touch alone.

Measurement is a process of associating with some feature of the world of experience a number which describes this feature in terms of some unit.

Iteration is the process of successively applying a unit or several units of a given magnitude of linear measurement to an object to determine the number of units in the object.

One-to-one correspondence is the process of matching one element of a set with an element of another set in such a way that a one to one relationship exists between the two elements. The nature of the elements matched from either set is irrelevant to the pairing.

IV. HYPOTHESES TO BE INVESTIGATED

This study will attempt to investigate the following hypotheses:

Hypothesis 1. There is no significant difference in the development of the basic concepts of linear measurement between grade one boys and grade one girls.

Hypothesis 2. There is no significant difference in the development of the basic concepts of linear measurement between grade one children of high mental ability, medium mental ability and low mental ability.

Hypothesis 3. There is no significant difference in the development of the basic concepts of linear measurement between grade one children of high socio-economic status and grade one children of low socio-economic status.

Hypothesis 4. There is no significant difference in the development of the basic concepts of linear measurement between grade one children who had been exposed to Numbers We Need by Brownell and Weaver[2], grade one children who had been exposed to Seeing Through Arithmetic by Hartung et al[3] and grade one children who had been instructed by the Cuisenaire method.

V. ORGANIZATION OF THE REMAINDER OF THE THESIS

Chapter II will be devoted to a review of the literature relative to measurement. It will trace the evolution of two distinct approaches to the development of the concept of measurement. Chapter III will contain a description of the sampling procedures to be used in analysing the results. In chapter IV the findings of this experiment will be reported as well as the results of the subsidiary experiment

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[2]William A. Brownell and J. Fred Weaver, Numbers We Need (Toronto: Ginn and Company).

[3]Maurice L. Hartung, Anita Ross and Catherine Mahoney, Seeing Through Arithmetic (Chicago: Scott, Foresman and Company, 1948).

with children who had only been exposed to the Cuisenaire method of arithmetic instruction. The findings of this investigation will be summarized in the final chapter together with some recommendations for further research.

CHAPTER II

A REVIEW OF RELATED LITERATURE

Measurement is a process of associating with some feature of the world of experience a number which describes this feature in terms of some unit, that is, it is the application of numbers in describing the properties of objects, events, phenomena and the like. For example, a thirty-four inch baseball bat may weigh thirty-four ounces and may cost three dollars and forty cents. In each instance numbers are used to give the magnitude of a property of the object. Investigations have been conducted in this area and attempts have been made to evaluate young children's knowledge and awareness of mea surement ideas and to discover the manner in which children acquire these concepts.

I. STUDIES RELATED TO INVENTORY-TYPE TESTS

The experimental studies in this group shared one basic research design, that is, they used an interview inventory-type test to determine young children's familiarity with common measuring devices. MacLatchy (1950) devised such a test. The test consisted of an extensive list of common measurement usage such as time, calendar, seasons, weight, length and money. For instance the child was shown a calendar and given such directives as: What is

it? Show me a day. Show me a week. Using this instrument with seventy-three pre-school children ranging in age from three to five years, she reported consistent growth in the child's familiarity with measurement.

Spayde (1953) administered MacLatchy's test, "Pre-School Child's Familiarity with Measurement", to one hundred eight kindergarten children in Lakewood, Ohio. He concluded that these children had only acquired the terms used and their familiarity had no real content. They simply recalled words or phrases in their habitual content.

Davis, Carper and Crigler (1959) employed this approach with twenty-three four-year-old pupils enrolled in a nursery school and twenty-nine five-year-old pupils enrolled in the kindergarten of a campus demonstration school. These investigators noted marked differences in familiarity with measurement between the responses of four-year-old and five-year-old children despite the fact that the older children had not achieved mastery of the ideas. They concluded that pre-school children have some understanding of common measures and that significant growth may occur between the nursery school and kindergarten years for some common measures.

An inventory-type test was used by Mascho (1961) with one hundred fifty beginning grade one children in the public schools of Muncie and Kokomo, Indiana. He wished to ascertain

these children's familiarity with measurement and to determine the effect of certain selected variables such as chronological age, socio-economic status, mental ability, sex and attendance or non-attendance in kindergarten on the development of a familiarity with measurement at this level. He found that beginning grade one children's familiarity with measurement increaded with increasing chronological age, higher mental ability and heightened socio-economic status. Sex and attendance or non-attendance in kindergarten did not appear to contribute to the child's familiarity with measurement. He also reported that there seemed to be a wide range in the child's familiarity with measurement. It was greater when the terms were used in context than when the terms were treated as isolated factual situations. First money then time were those aspects of measurement most familiar to these children. Mascho concluded from his investigation that the children were less familiar with measurement than would have been predicted from the findings of other investigators.

Farrell (1953), using a question type test, investigated understandings of time relations of five-, six-, and seven-year-old children of high intelligence to discover what relationships existed, if any, between time and chronological age, mental age and sex. A questionnaire composed of twenty-seven items was given to seventy-five children

from Hunter College Elementary School in New York city. The questionnaire was designed so that factual past, present, and future complex time concepts could be evaluated. Generally, the first part of a question required a factual answer, for example, what day is today? The second part required a cue answer, for example, how do you know today is Monday? No significant difference was found to exist between the six and seven year olds in their understanding of time relationships. However significant differences were found between the five and six year olds and the five and seven year olds. The six- and seven-year olds answered significantly better the "present" questions than either the "past" or "future" questions. No significant difference was found between understanding of time relations and either sex or mental age. She concluded that the results indicated a growth of time understanding between the five and six year old levels but not between the six and seven year old levels. The reason for such a development is not obvious. The questions used may have been inadequate for testing the seven-year old group. The six-year old group answered many questions with such a high percentage of accuracy that there remained little room for improvement for the seven-year old.

Bjonerud (1960) attempted to discover some of the specific number and measurement concepts possessed by the pre-school child at the time of kindergarten entrance. In

the fall of 1957 he selected one hundred beginning kindergarten children in the public schools of Livonia, Michigan. The study was repeated in February 1960 with twenty-seven pupils selected from a mid-year class of beginning kindergarten children in a demonstration school. Two tests, an individual oral interview and a written picture test were developed. The measurement aspect of this study was mainly concerned with the ability of the child to name and recognize common instruments of measurement. He concluded that some thought should be given to possible adjustments in the presentation of arithmetic concepts in the kindergarten or the first grade. An inventory of the child's measurement concepts should be made during the first part of the first year at school so that more emphasis can be placed on developing understandings for those children whose background experiences have been more limited.

II. STUDIES RELATED TO PIAGETIAN-TYPE TESTS

Piaget (1952) contended that conservation is a necessary condition for all rational activity. Conservation can be defined as the invariance of a given quantity; that is, a given quantity remains the same regardless of the arrangement or rearrangement of its parts. A continuous quantity such as volume, weight, time, length can be used with understanding only if it is a permanent whole regardless of the

arrangement of its parts. Therefore, conservation is postulated as a necessary condition for any mathematical understanding.

Piaget had devised a number of ingenious experiments which had been designed to test a child's knowledge and stages in the development of such concepts as conservation of quantity, ordinal and cardinal correspondence, ordinality and cardinality of number, various aspects of measurement, for instance, length, weight, time, volume.

The Piagetian method was essentially a combination of interview, observation, and recording. He postulated three distinct stages in the conceptual development of children. The first stage was essentially one of non-conservation in which the child is unable to cope with the demands of the particular test. His perceptions are unco-ordinated. The second stage is transitory. For instance a child in this stage can be induced to set up a one-to-one correspondence between two sets of objects by placing one object from one set with a corresponding object from the second set until all the objects have been paired. Changing the distribution of the elements of one set, destroys in the child's mind, the equivalence relationship which he had established. The final stage is one in which the child successfully solves all the problems. His judgments are now "operational", that is, he is mentally capable of visualizing the operation and

anticipating the results.

Piaget, Inhelder and Szeminska (1962) outlined their views on the way in which a child comes to understand the concept of length and measurement. In one of the experiments based on spontaneous measurement, the child was shown a tower made of twelve blocks about two and a half feet high. The tower stood on a table. The child was required to construct a similar tower on a second table which was six feet away and which was three feet lower than the first table. A large screen was placed between the two tables but the child was encouraged to check the model as often as he wished. He was provided with paper, sticks, rulers but he was not shown how to use them. Three developmental stages were observed. In the first stage, which lasted to about four and a half years of age, the child only made a visual comparison. The towers were estimated to be the same height and the difference in the heights of the table tops was ignored. In the intermediate stage which lasted roughly from four and a half years to seven years of age the child recognized that the heights of the table tops were not the same. Still he could not construct a tower similar to the model in spite of the fact that he attempted to measure using various parts of his body as a measuring instrument. In the final stage, from seven years on, the child constructed a tower similar to the model using a measuring device such as a stick.

In another experiment, Piaget, Inhelder and Szeminska (1962) studied how children judged and conserved distance. Two toy trees of the same height were placed twenty inches apart. The child was required to estimate whether they were near one another or far apart. A screen was then inserted between the trees and the question restated. To study the development of the conservation of length the children were confronted with two identical straight sticks. They were parallel to one another with their extremeties coinciding. The children were asked to compare the lengths of the sticks. One stick was moved slightly and the question was restated.

To determine whether children could conserve length when the length of one of the objects was modified, the children were faced with two parallel rows of six matches each placed end to end. After the children had ascertained that the two "lines" were equal in length, one of the "lines" was rearranged to form a right angle and then again to form a series of zig-zags. The children were then required to judge whether these two "lines" were still the same in length.

In each instance, three developmental stages were reported: The first characterized by non-conservation, the second represented a stage in transition where the child could conserve under certain circumstances, and the third described the child who comprehended the invariance of dis-

tance or length irrespective of the internal arrangements. The experimenters concluded that the concept of linear measurement depends upon logical thinking. The child must understand that a segment can be composed of a number of parts joined together end to end. In addition, the child must comprehend the principle of iteration; that is, the repeated application of a unit segment to a larger segment.

Lovell, Healey and Rowland (1962) carried out a number of experiments with seventy-five English primary school children aged five to eleven. These tests attempted to discover the level at which a child, in his conceptual development, would conserve distance and length and would successfully subdivide a straight line. They concluded that the replies of the children agreed fairly well with those given by Piaget and that the stages that he suggested seem to be there in the case of many children. They felt that mental age rather than chronological age was a better guide to the stages of development. There was also evidence that the repeated application of a given fixed length, that is, the process of iteration, involved thinking skills which develop with age. They found that it was easier for a child to measure a length which was shorter than the measuring device.

Lovell and Ogilvie (1960) conducted a series of experiments which purported to test the growth of children's concepts of conservation of quantity. They examined indi-

vidually three hundred twenty-two English junior school children, ages seven to eleven. Again Lovell and Gilvie (1961) individually tested three hundred sixty-four children in a large English junior school along the lines initiated by Piaget in an attempt to trace the development of the conservation of weight. As a result of their studies of the development of junior school children's concepts of substance and weight, they concluded that strong evidence had been produced in support of the three stages proposed by Piaget. But, the stages are not clear cut; the borders between them are zones not lines. There were junior school children from each of the school year levels and from each age group at all three developmental stages. Generally the number and percentage of conservers of both substance and weight tended to increase with maturation and years in school. Conversely, the number and percentage of non-conservers tended to decrease with maturation and years in school. Lovell[4], as a result of these experiments stated:

> The concept of substance arises earlier than that of weight since quantity is under immediate perception whereas weight is not.

In a systematic replication of Piaget's experiments which were designed to determine the development of chil-

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[4]K. Lovell, The Growth of Basic Mathematical and Scientific Concepts in Children (London: University of London Press Ltd., 1961), p. 74.

dren's quantitative thinking, Elkind (1961) interviewed eighty school and pre-school children. They were divided into three age groups--four, five, six to seven and tested for three types of quantity which he identified as either gross, or intensive, or extensive. Elkind concluded that the results were in close agreement with Piaget's conclusions, that is, success in comparing quantity developed in three hierarchically ordered stages.

Lovell (1959) studied the performance of one hundred fifty nursery school English children ranging in age from two years eleven months to five years eight months on tests which were designed to determine children's conception of space. He found that the relative difficulty of items from the point of view of identification remained roughly the same from age group to age group. Generally there was no significant difference between the performance of boys and the performance of girls. Young children found that straight sides and angles are the most difficult to distinguish by haptic perception. He was able to show that children could construct figures with match-sticks at least six months earlier on the average than they could draw them.

III. CONCLUSIONS

From this review of the literature it can be inferred that little attention has been given to research in young

children's acquisition of measurement concepts. Attempts to determine the extent of young children's knowledge of measures of common usage revealed that the verbalization of the terms should not be used as a criterion for understanding of the underlying ideas. Piaget's study of the underlying psychological processes in the development of young children's conception of measurement has widened the scope of educational inquiry and stimulated other researchers to undertake systematic studies of developmental and learning patterns of children.

As a result of this review of the literature concerning concepts of measurement, one can conclude:

1. that measurement concepts appear to develop through three continuous stages, that is, first, a stage of non-conservation; second, a stage of transition; and third, a stage of conservation.
2. that familiarity with measurement concepts increases with increasing chronological age, higher mental ability, and heightened socio-economic status.
3. that there is a wide range of familiarity with the measures of common usage among beginning school children.
4. that understanding of the basic measurement concepts appears to begin at about six or seven years of age.

CHAPTER III

DESIGN OF THE EXPERIMENT

This chapter will be devoted to a discussion of the procedures followed in conducting the investigation and the statistical processes employed in the analysis of the data.

This investigation was carried out in grade one classes of the city of Edmonton Public Schools. Permission was obtained from the Superintendent, Mr. W. P. Wagner, to conduct the study. Miss A. Carmichael, Primary Supervisor, allocated ten schools selected on the basis of socio-economic status and arithmetic program. A random sample of grade one children stratified on the bases of sex, mental ability, arithmetic program and socio-economic status was selected. The Primary Supervisor requested, and this investigator concurred, that this study be extended to a small group of grade one children who had been exposed exclusively to the Cuisenaire method of arithmetic instruction. The investigation in this one school constituted a subsidiary inquiry.

A series of tests was devised and administered by the investigator during the month of June, 1964. The tests were then scored and the scores were statistically analysed.

I. POPULATION AND SAMPLE

The population consisted of all grade one children

who were in attendance in the city of Edmonton Public Schools during June, 1964, and who had been exposed to such arithmetic programs as described in Numbers We Need[5], Seeing Through Arithmetic[6] and the Cuisenaire method. Henceforth NWN will refer to Numbers We Need and STA will refer to Seeing Through Arithmetic.

From data available at the School System's central office, the Primary Supervisor allocated ten schools representing three socio-economic levels. Three schools were in areas considered to be at a high socio-economic level, four were in areas considered to be at an average socio-economic level and three were in areas considered to be at a low socio-economic level. Of these ten schools, five were using the NWN series at the grade one level and five were using the STA series at the grade one level. From records in each of the ten schools it was possible to acquire the following information about each of the 738 children who were in attendance in June 1964: (1) whether boy or girl; (2) mental ability--from scores obtained on the Detroit Beginners' Intelligence Test given to all grade one children in September 1963. The range for these children on this test was from 68 to 151. Children who had scored 120 and over

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[5]Brownell and Weaver, loc. cit.

[6]Hartung, Ross and Mahoney, loc. cit.

were judged to have high mental ability. Children with scores less than 95 were judged to have low mental ability. Those children from 95 to 119 were considered as possessing average mental ability; (3) level of socio-economic status was based on the father's occupation or on the mother's if the father was deceased or was separated from his family for any reason. Those who scored fifty or more on the Blishen Occupational Class Scale[7] were judged to come from high socio-economic homes. Those who scored less than fifty were judged to come from low socio-economic homes.

The main sample was then selected by assigning a number to each of the 738 grade one children in the ten schools and selecting 120 using a table of random numbers.[8] Thus the principal sample consisted of sixty children using the WN program and sixty children using the STA program. It was not possible to select from the Cuisenaire group a random sample stratified on the basis of the four main factors. The predominant low socio-economic backgrounds of the children precluded the use of this factor. In addition the

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[7]Bernard R. Blishen, The Construction and Use of an Occupational Class Scale (Toronto: Macmillan, 1961), pp. 477-485.

[8]Wilfrid J. Dixon and Frank J. Massey, Introduction to Statistical Analysis (New York: McGraw-Hill, 1957), pp. 366-367.

unequal distribution of boys and girls at the three levels of mental ability further impaired the resultant selection. Since the total group consisted of sixty-one children it was decided to select an auxiliary sample of twenty children using, as much as possible, the same selective procedure as described for the main study. Therefore the Cuisenaire group consisted of eight boys and twelve girls--two boys and five girls were designated as possessing high mental ability; three boys and four girls were judged to have medium mental ability; and three boys and three girls were considered as possessing low mental ability.

II. THE ARITHMETIC PROGRAMS

At the grade one level the STA series emphasized the idea of a unit of measurement. Starting with such basic ideas as the crude comparison of objects of various sizes, the children are guided through a series of activities--for example, a stick of any convenient length is used to measure a variety of familiar things (the length of the blackboard, the width of an easel, the height of a child, the length of a broom, the height of a desk, the width of a book). The children are expected to note for themselves that the stick may be a little longer than the object being measured, a little shorter, or exactly the same. These and similar experiences are aimed at developing in the children

the need for a standard unit. Once this concept has been attained the children should be ready for measurement in terms of foot, inch, yard. Finally, in a similar development the grade one children are guided through a sequence of experiences leading to the acquisition of the concept of volume or capacity.

It is the opinion of the authors that the telling of time using the clock or calendar should be learned through the regular use of these devices in connection with the various daily activities of the classroom.

The NWN series almost ignored the problem of measurement at the grade one level. The children are first faced with the identification of measuring instruments in situations familiar to them--such as the matching of a picture of a boy removing a jacket under a blazing sun with a picture of a thermometer registering eighty degrees above zero. The treatment of the concept of time consisted of widely dispersed exercises dealing with the telling of time on the hour. Comparing the sizes of objects constituted the only treatment of measurement as a concept related to length or capacity. Finally, a few experiences with such simple geometric figures as the line, circle, square and triangle completed the measurement aspects of this arithmetic program.

The Cuisenaire method of arithmetic instruction is

primarily concerned with the development of the concept of number using structured materials. As a result no direct reference is made to ideas related to measurement. Hence grade one children may only be incidentally exposed to ideas relevant to the concept of measurement.

III. THE INSTRUMENT

Since the test was designed to determine to what extent some of the more important aspects of the basic concepts of linear measurement have developed in children who had been attending grade one for nine months, a review of tests used in previous studies was of great assistance. Some of the test items devised by Piaget and Lovell and mentioned previously were used. The balance was designed by the investigator.

In order to refine the test and to phrase the questions in language which would be comprehensible to grade one pupils it was administered to a group of seventeen children who were attending a school not included in the sample. On the basis of this initial study, the test was further revised. Some items were completely eliminated from the test and some of the questions were restated in a language more meaningful to grade one children. For example, subtest VI originally consisted of two twenty-inch rods and one twelve-inch rod. The latter was eliminated because it only

served to compound the problem while the former produced sufficient information for the purposes of this study.

As a result of this preliminary investigation, the final draft of the experiment consisted of six subtests each designed to determine the extent to which some concepts of linear measurement had developed in these children. A copy of the test, A Test for Measurement Readiness, is given in appendix A. The following is a description of the various subtests and the concepts which they were designed to measure:

I. Reconstructing Relations of Distance

This test was designed primarily to determine how the child judged distances and whether he could conserve distance. It consisted of two dolls, each five inches tall, facing each other about twenty-five inches apart. One doll was standing on a metal can, four and a half inches high. The child was asked to judge the distance between the two dolls. This procedure was first repeated by placing a screen, eight inches high and twelve inches long, between the dolls. The screen was removed and a rectangular solid, two inches by three inches by twelve inches, was placed between the dolls.

II. Conservation of Length

This test was designed to determine the child's ability to conserve the length of an object. It considered the length of lines and the coincidence of their extremities.

Each child was confronted with a straight thin stick ten inches in length and an undulating piece of string about fifteen inches long. The objects were placed side by side with their extremities in exact alignment. Each child was asked to state which object was longer or if they were both the same and to give a reason for his answer. The string was then straightened and the question was repeated. Finally the string was returned to its original shape as in step one of this test and the same question was repeated.

III. Conservation of Length with a Change of Position

The purpose of this test was to determine the child's ability to conserve length after the position of one of the objects had been changed. Two rods (actually two Cuisenaire ten rods) about four inches in length were placed on a table so that their endpoints were coterminous. Each child was asked to compare the lengths of the rods. The same question was repeated with rod placement being altered as follows: 1) the rod closest to the child was pushed half an inch to the left; 2) the two rods were placed to form the letter T; and 3) the two rods were placed to form an acute angle.

IV. Conservation of Length with Distortion of Shape

This test was designed to determine the child's ability to conserve length after the length of one of the objects had been modified. This test consisted of two parts. In the first part the child was confronted with twelve

counting sticks arranged in two parallel lines, one inch apart on a table, of six counting sticks each. The child was asked to compare the lengths of these two lines of counting sticks. The line closest to the child was rearranged to form a right angle. Some of the sticks were broken to prevent counting. The question was repeated. In the second part, two strips of paper each fourteen inches long and one half inch wide, were placed side by side on a table. Each child was asked to compare the lengths of the strips of paper. One strip of paper was then cut several times and the question was repeated.

V. Measurement of Length

This test was designed to determine the child's ability to measure without the use of standard units of measurement. The child was presented with strips of cardboard arranged in various shapes and pasted to a hard-backed material. The child was asked to compare these lines as to their linear equality or inequality. The child was then given a supply of short strips of unmarked cardboard two inches, four inches and six inches in length to verify his previous appraisal.

VI. Subdividing a Straight Line

This test was designed to determine the child's ability to measure spontaneously when he was confronted with a variety of measuring situations. The child was required

to select an appropriate measuring instrument from a set of units which were regarded as being standardized for the purpose of this test. These standardized units were one stick measuring three inches, another measuring ten inches and a third measuring thirty inches. Two straight twenty-inch rods each with a bead that was free to move along it were placed on a table. Each child was confronted with a variety of measuring situations.

IV. THE TESTING PROGRAM

This testing program was undertaken in the schools during the period June 1 to June 20, 1964. The test was administered to individual children by the investigator who recorded each child's responses. Where conditions were favorable the responses of some children were recorded on tape. The responses of twenty-three children were recorded. The tests were conducted at each of the ten schools and in each case the testing was carried out in a convenient area apart from the classroom to minimize interruptions. Only the child and the investigator were present during the tests.

The objects to be used for the test were arranged at six testing stations, corresponding to the six subtests. Careful attention was given to seeing that the test situation was consistent from child to child and from one school to another. The experiment began with the first subtest and continued in sequence through all the subtests. The actual

test time varied greatly from a minimum of ten minutes to a maximum of thirty minutes.

V. THE ANALYSIS TO BE USED

The items in the test were scored by assigning a one or a zero to each, depending upon whether the child was able to arrive at the correct answer or not. It was assumed that if the child could give the correct answer or perform correctly the proper operation with the objects, then he had some knowledge of the concept involved. He was therefore assigned a score of one for that particular item. On the other hand if the child could not give the correct response or was unable to manipulate the items in each subtest, it was assumed that his familiarity with that particular concept was inadequate. He was therefore assigned a score of zero for that item. It was then possible to arrive at a total test score by summing all the correct responses for each child. Those items which elicited explanatory responses from the children were recorded but not scored.

Since the study was determining the simultaneous effect of sex, mental ability, socio-economic status and arithmetic program on the development of the concepts of linear measurement the children's test scores were arranged in a two by three by two by two matrix. A four-way analysis of variance was used in treating the data. t tests of

significance were considered suitable for the treatment of the results obtained from the testing of the children who had been exposed to the Cuisenaire method of arithmetic instruction when compared with those of children who had been using the NWN and STA programs.

The analysis tested all the data at the five per cent level of significance.

CHAPTER IV

SUMMARY AND ANALYSIS OF RESULTS

This chapter is concerned with a summary and analysis of the results of the test. In order to determine to what extent grade one children's conception of linear measurement had developed after nine months of formal instruction, a sample of one hundred twenty children representing sixty children who had had the NWN arithmetic program and sixty children who had used the STA arithmetic program was selected. An auxiliary sample of twenty grade one children who had been instructed by the Cuisenaire method was also selected. Six subtests were devised and were administered individually to these children by the investigator during the spring of 1964. These subtests attempted to discover the impact of different arithmetic programs considered simultaneously with mental ability, sex and socio-economic status on the development of some of these concepts of measurement.

Hypothesis 1

There is no significant difference in the development of the basic concepts of linear measurement between grade one boys and grade one girls.

Hypothesis 2

There is no significant difference in the development

of the basic concepts of linear measurement between grade one children of high mental ability, medium mental ability and low mental ability.

Hypothesis 3

There is no significant difference in the development of the basic concepts of linear measurement between grade one children of high socio-economic status and grade one children of low socio-economic status.

Hypothesis 4

There is no significant difference in the development of the basic concepts of linear measurement between grade one children who had been exposed to the NWN arithmetic program, grade one children who had been exposed to the STA arithmetic program and grade one children who had been instructed by the Cuisenaire method.

I. NATURE OF THE SAMPLE

The sample for the central problem consisted of 120 grade one children randomly chosen from 738 children who had been in attendance for nine months in ten schools from September 1963 to June 1964. The selected schools were judged to be representative of the total grade one population in the city of Edmonton Public Schools. Of these schools, five were using the NWN series at the grade one

level and the other five were using the STA series at the grade one level. The subsidiary sample consisted of twenty grade one children who had been selected from sixty-one children who had received Cuisenaire arithmetic instruction.

Table I shows the distribution of the chronological ages of the boys and girls in the two samples. There was a two year age range from six years five months to eight years five months. The mean age was six years 11.56 months or approximately seven years. Seventy-three children or 52.1 per cent were less than seven years of age and fifty-five children or 39.3 per cent were above the average age for the group. Of the latter, two, both boys, were more than eight years of age. Excluding these two from the sample reduced the mean age to six years 11.10 months, a difference of about two weeks. A comparison of the mean ages of the boys and girls revealed that the girls were 1.21 months younger than the boys. The mean age of the boys was seven years 0.07 months while the mean age of the girls was six years 10.86 months.

Table II shows the distribution of the total scores of all grade one children tested. Scores ranged from a low of two to a high of twenty. The latter score was achieved by a boy with medium mental ability from a low socio-economic background who had received arithmetic instruction from the STA series. The former score was realized by two girls with

TABLE I

CHRONOLOGICAL AGES OF CHILDREN IN MAIN AND SUBSIDIARY SAMPLES

Age* (years & months)	NWN		STA		Cuisenaire		Total
	Boy	Girl	Boy	Girl	Boy	Girl	
6-5	2	0	0	1	0	0	3
6-6	3	3	4	1	0	2	13
6-7	1	2	4	6	0	3	16
6-8	1	2	1	6	1	0	11
6-9	2	5	1	1	1	0	10
6-10	4	4	1	1	0	1	11
6-11	2	1	4	1	1	0	9
7-0	1	3	2	2	1	3	12
7-1	3	3	2	4	2	2	16
7-2	3	2	1	2	0	0	8
7-3	3	0	4	1	1	0	9
7-4	3	0	1	1	1	0	6
7-5	1	3	1	2	0	0	7
7-6	0	1	0	0	0	0	1
7-7	0	0	0	0	0	0	0
7-8	0	1	1	0	0	1	3
7-9	0	0	1	1	0	0	2
7-10	0	0	1	0	0	0	1
7-11	0	0	0	0	0	0	0
8-0	0	0	0	0	0	0	0
8-1	0	0	0	0	0	0	0
8-2	0	0	1	0	0	0	1
8-3	0	0	0	0	0	0	0
8-4	0	0	0	0	0	0	0
8-5	1	0	0	0	0	0	1
Total	30	30	30	30	8	12	140

*Age was computed to the nearest month as of June 1, 1964.

TABLE II

TEST SCORES OF THE GRADE ONE CHILDREN

		Arithmetic Program				
		NWN		STA		Cuisenaire
		Socio-economic Status				
		High	Low	High	Low	
Boy	High Mental Ability	13	16	5	7	18
		5	6	4	19	9
		14	5	3	17	
		9	7	12	18	
		7	4	15	13	
	Medium Mental Ability	7	7	6	20	5
		5	5	12	3	10
		9	6	8	3	6
		5	13	12	7	
		3	7	14	7	
	Low Mental Ability	9	7	5	4	4
		8	7	7	8	6
		8	8	7	11	9
		8	14	7	10	
		7	6	3	4	
Girl	High Mental Ability	13	13	7	12	10
		8	7	14	13	12
		6	6	7	8	5
		11	13	10	6	5
		6	6	5	15	6
	Medium Mental Ability	6	17	5	7	9
		13	9	5	13	4
		11	8	14	4	4
		5	8	16	8	4
		8	8	6	14	
	Low Mental Ability	6	4	14	9	7
		6	4	16	3	2
		5	6	8	6	4
		2	6	13	7	
		4	7	8	4	

low mental ability: one from the Cuisenaire group, the other from the NWN group--a child judged to possess a high socio-economic status.

Further examination revealed that the cell with the greatest frequency of high scores turned out to be that of the five boys with high mental ability and low socio-economic status who had been exposed to STA. The cell with the next recurrence of high scores turned out to be that of the five girls with the same background representing the same arithmetic program as the above mentioned five boys. The cell with the highest frequency of low scores turned out to be that of the five girls with low mental ability and high socio-economic status who represented the NWN series.

Further analysis of the scores revealed that the grade one children who had been instructed from the STA arithmetic series enjoyed more success with the test than those children who had been exposed to the NWN series or Cuisenaire method.

II. DISCUSSION OF TEST RESULTS

A copy of the test used is to be found in Appendix A. It consists of six subtests. Maximum test score was twenty-five. The number of items varied from one subtest to another and was hierarchically arranged according to difficulty. Subtest I dealt with children's differing concepts of

distance and length. Subtests II, III and IV were concerned with the conservation of length of various items. Subtest V attempted to discover whether grade one children could measure spontaneously without the use of common standardized units. Subtest VI was designed to discover whether these children could subdivide a straight line, a necessary condition to an understanding of the concept of linear measurement.

Each item in the six subtests was scored by assigning a one or a zero to each, depending on whether the child arrived at the correct answer or not. Item difficulty, expressed by the percentage of children who had been successful, is shown in Table III. An examination of the results revealed a pattern of increasing item difficulty. After item five generally less than one-half of the children had any success with the items of the subtests. After item fourteen less than one-quarter of the children could manipulate the test instruments. After item seventeen less than one-twelfth of the children had any understanding of the concepts the test was to determine. Items nine and twenty contravened the described trend. The former was the last manipulation of subtest III where the two sticks were placed to form an acute angle. Because the sticks were aligned many (eighty-five per cent) of the children judged with certainty that the two sticks were now equal in length. They

TABLE III

DIFFICULTY ON ITEMS IN SUBTESTS I TO VI

Test	Item	Per Cent Successful			
		NWN	STA	Cuisenaire	Total
I	1	53.3	50.0	55.0	52.7
	2	53.3	48.3	40.0	47.2
	3	48.3	61.7	20.0	43.3
II	4	61.7	65.0	70.0	65.6
	5	100.0	100.0	100.0	100.0
	6	33.3	35.0	15.0	27.8
III	7	31.7	38.3	5.0	25.0
	8	33.3	41.7	15.0	30.0
	9	78.3	83.3	95.0	85.0
IV A	10	33.3	51.7	40.0	41.7
IV B	11	38.3	53.3	35.0	42.2
	12	36.7	43.3	35.0	38.3
	13	35.0	40.0	25.0	33.3
V A	14	21.7	25.0	10.0	18.9
	15	6.7	18.3	10.0	11.7
	16	11.7	18.3	10.0	13.3
V B	17	10.0	20.0	10.0	13.3
	18	3.3	10.0	5.0	6.1
	19	5.0	8.3	5.0	6.1
VI	20	71.7	60.0	95.0	75.6
	21	0.0	10.0	5.0	3.0
	22	0.0	10.0	5.0	3.0
	23	6.7	10.0	5.0	7.2
	24	1.7	8.3	5.0	3.0
	25	1.7	10.0	5.0	5.6

had changed their minds although most of them had previously stated that one of the sticks was longer than the other. The latter was the first step of subtest VI where the inves-

tigator's bead was moved a short distance and the children were required to move their bead an equal distance from the same end. The majority (about seventy-five per cent) of the children performed this correctly by visually estimating the distance. Few used the standard units that were provided.

Results of Subtest I - Reconstructing Relations of Distance

This subtest was designed to determine how the child judged distance and whether he could conserve distance. Conservation of distance is basic in the child's acquisition of the concept of linear measurement. The subtest consisted of six questions of which three were scored. Table IV shows the distribution of scores.

TABLE IV

SUMMARY OF SCORES OF SUBTEST I

Scores	Per Cent of Children Achieving Score			
	NWN	STA	Cuisenaire	Total
3	16.7	21.7	10.0	16.1
2	35.0	35.0	20.0	30.0
1	31.7	20.0	45.0	32.2
0	16.7	23.0	25.0	21.6

Although about one-sixth of the children had obtained a score of three and had displayed an understanding of the

concept of distance, a similar number had not yet mastered this concept. About sixty per cent of the children had some notion of the concept. Although the STA group was slightly more successful in the test--21.7 per cent to 16.7 per cent of the NWN group and 10.0 per cent of the Cuisenaire group--it had a large number of students who had not grasped this concept.

A more detailed analysis of the results of subtest I is shown in Table V. For about one-third of the children doll B (on the can) was definitely judged to be farther from doll A than doll A from doll B. They rationalized that this

TABLE V

SUMMARY OF RESULTS OF SUBTEST I

Item	Activity	Per Cent Response For Each Item			Total
		NWN	STA	Cuisenaire	
1	Farther from doll A[1] to doll B[2]	1.7	6.7	10.0	6.1
	Farther from doll B to doll A	38.3	40.0	35.0	37.8
	Same distance	53.3	50.0	55.0	52.8
	Couldn't or wouldn't	6.7	3.3	0.0	3.3
2	Closer together	13.3	13.3	15.0	13.9
	Farther apart	35.0	40.0	45.0	40.0
	Same distance	51.7	46.7	40.0	46.1
3	Closer together	16.7	15.0	15.0	15.6
	Farther apart	35.0	23.3	65.0	41.1
	Same distance	48.3	61.7	20.0	43.3

[1]Doll A - standing on the table.
[2]Doll B - standing on a four inch can.

condition existed because doll B was higher than doll A. Furthermore a similar number of children was certain that the distance between the two dolls increased after the screen or the solid had been placed between the dolls. The part-whole relationship, a necessary condition in the development of conservation concepts, had not become operational. For some children (about fifteen per cent) the insertion of the screen or the solid between the dolls served to bring them closer together. These ignored the space occupied by the inserted object and only concentrated on the distance from the dolls to the object.

Results of Subtest II - Conservation of Length

This subtest was designed to determine the child's ability to conserve the length of lines and the coincidence of their extremities. The test consisted of three questions and two objects, a ten-inch stick and a fifteen-inch piece of string. The length of the string was arranged so as to elicit a judgment response from each child when it was compared to the stick. Table VI shows the distribution of scores.

About one-fourth (26.1 per cent) of the total group obtained a score of three thus displaying an ability to conserve the length of objects when their extremities were considered. A larger number of the students of the NWM program was successful in this test. This was the only subtest in

which these students displayed a slight superiority over the students representing the STA.

TABLE VI

SUMMARY OF SCORES OF SUBTEST II

Score	Per Cent of Children Achieving Score			
	NWN	STA	Cuisenaire	Total
3	33.3	30.0	15.0	26.1
2	28.3	38.3	55.0	40.5
1	38.3	31.7	30.0	33.3
0	0.0	0.0	0.0	0.0

A more detailed analysis of the results of subtest II is shown in Table VII.

TABLE VII

SUMMARY OF RESULTS OF SUBTEST II

Item	Activity	Per Cent Response For Each Item			
		NWN	STA	Cuisenaire	Total
4	String longer	61.7	63.3	70.0	65.0
	Stick longer	6.7	5.0	5.0	5.6
	Both the same	31.7	31.7	25.0	29.5
5	String longer	100.0	100.0	100.0	100.0
	Stick longer	0.0	0.0	0.0	0.0
	Both the same	0.0	0.0	0.0	0.0
6	String longer	31.7	35.0	15.0	27.2
	Stick longer	1.7	1.7	10.0	4.5
	Both the same	66.7	63.3	75.0	68.3

The results of item four show that sixty-five per cent selected the string as being longer and 29.5 per cent thought that the string and the stick were both the same length. Although the results of item five confirm the fact that all the children knew that the string was longer, the results of item six show that less than one-third was still sure after the string was returned to its original shape.

From the responses of the children who had not grasped this conservation concept it was obvious that they were only considering the ends of the "lines" and were not concerned with the internal shapes of the objects. Many of them, when considering the ends of the "lines", placed their hands (palms inward) at the coinciding ends of the string and the stick, and indicated that the distance between their hands was the same. Others brought their eyes to the level of table and carefully considered the ends of the "lines" and stated: "They're even here and here."

Results of Subtest III - Conservation of Length

This subtest was designed to determine the child's ability to conserve length after the position of one of the objects had been altered. The subtest consisted of three questions which required the child to ascertain whether the two sticks were still the same length after the position of one of the sticks had been changed. Table VIII shows the

distribution of scores.

TABLE VIII

SUMMARY OF SCORES OF SUBTEST III

Scores	Per Cent of Children Achieving Score			
	NWN	STA	Cuisenaire	Total
3	25.0	35.0	5.0	21.7
2	11.7	6.7	5.0	7.8
1	45.0	43.3	85.0	57.8
0	18.3	15.0	5.0	12.8

About one-fifth of the children could conserve length after a change of position. Before the sticks were manipulated all the children were quite certain that the two sticks were equal in length. Yet 12.8 per cent of the children had no notion of this concept. As a matter of fact a number of the children who had been instructed by the Cuisenaire method quickly corrected this investigator whenever the word sticks was used: "They're not sticks, they are two ten-rods." Yet only about five per cent of them were able to conserve the length of the two ten-rods after the position of one had been altered.

The superior achievement of the children who had had experience with the NWN and STA series may be attributed to the crude comparative activities with objects that these two programs had incorporated into their grade one arithmetic

curriculum. Since STA's development was more comprehensive this may explain, in part, the better results of these children.

A more detailed analysis of the results of subtest III is given in Table IX.

TABLE IX

SUMMARY OF RESULTS OF SUBTEST III

Item	Activity[1]	Per Cent Response for Each Item			
		MWN	STA	Cuisenaire	Total
7	Stick AB longer	8.3	6.7	25.0	13.0
	Stick CD longer	60.0	55.0	65.0	60.0
	Sticks AB and CD same length	31.7	38.3	10.0	26.7
8	Stick AB longer	18.3	8.3	40.0	22.2
	Stick CD longer	50.0	50.0	50.0	50.0
	Sticks AB and CD same length	31.7	41.7	10.0	27.8
9	Stick AB longer	15.0	11.7	5.0	10.3
	Stick CD longer	6.7	6.7	0.0	2.2
	Sticks AB and CD same length	78.3	81.7	95.0	85.0

[1]After each item, stick CD was always closer to the child.

Over half of the children thought that stick CD was longer after it had been moved slightly to the left. They tended to concentrate on the left extremity of the sticks, completely ignoring the right extremity. They were quite satisfied that, since one end of one stick protruded, it was

longer. Again about one-half of the children thought that stick CD was longer after it had moved to form a T. Invariably the shape was compared to the letter T. A typical reply was: "You made it in a T. This looks smaller." (pointing to stick AB). However, after the sticks had been moved to form an acute angle, more than three-fourths of the children were quite certain that the sticks were now the same length. Many had changed their minds. Some children placed their hands (palms inward) at the ends of the sticks and stated that the sticks were the same. Others brought their eyes to the level of table and carefully considered the extremities of the sticks before exclaiming: "They're even. They're the same!" This development appears to substantiate the fact that the children were concerned with the extremities and ignored the space between the ends.

The Cuisenaire group seemed to experience more difficulty with the items of this subtest than the other children in the sample. In the Cuisenaire program rods are utilized to stimulate the development of the concept of number. Measurement appears to be of no consequence. Hence these children gained experience with rods of various sizes that always had to be aligned to solve a problem. This may explain the greater success of the group in the case of item nine where the two sticks were placed to form an acute angle. The rough alignment caused ninety-five per cent of

the children (a far greater proportion than either the IWW or STA groups) to state that the two sticks were now the same length.

Results of Subtest IV - Conservation of Length

The purpose of this subtest was to determine the child's ability to conserve length after the length of one of the objects had been modified. This subtest was divided into two parts.

In the first part, the child was confronted with two parallel lines, one inch apart, of six counting sticks each placed end to end. Once the child had ascertained that the two lines were equal, he was asked to decide whether the two lines were still equal after the investigator had rearranged one of the lines to form a right angle. Two sticks were broken to discourage counting. This part of the subtest was assigned a score of one. The results are shown in Table X. Slightly less than half was able to conserve the length of these two lines of sticks. "If put back, same size." or "They're all the same in inches, one is bent now." were representative replies of these children.

In the second part, the child was confronted with two fourteen-inch strips of paper placed side by side on a table with their ends in exact alignment. Once the child was satisfied that these two strips of paper were the same length, one strip, the one closer to the child, was cut several

TABLE X

SUMMARY OF SCORES OF SUBTEST IV

Part	Scores	Per Cent of Children Achieving Score			
		NMI	STA	Cuisenaire	Total
1	1	33.3	51.7	40.0	41.7
	0	66.7	48.3	60.0	48.3
2	3	21.7	30.0	10.0	20.6
	2	11.7	11.7	20.0	14.5
	1	21.7	23.3	25.0	23.3
	0	45.0	35.0	45.0	41.7

times. The child was then required to determine whether the two strips of paper were still the same length. This part of the subtest consisted of three questions and a score of three was possible. Results are shown in Table X. About one-fifth of the children were able to conserve the length of these two strips of paper. From the first to the second part of this subtest, the proportion of successful children was halved.

More detailed results are shown in Table XI.

Almost half (forty-five per cent) of the children thought that line AB (the line of sticks which was not moved) was longer after line CD was rearranged. The majority of these were convinced that line AB was longer because it was "straight across". It is felt that these children were really looking at the ends of the lines. Since line CD was shaped "like a square" it occupied less lateral space on the

table and hence was less long. The ends of line AB projected beyond the ends of the line CD. Therefore line AB had to be longer. In addition some stated that breaking the sticks automatically made that line of sticks shorter. Something in the line had been taken away. Pointing to line AB, some children said: "It has more sticks."

TABLE XI

SUMMARY OF RESULTS OF SUBTEST IV

Part	Item	Activity	Per Cent Response for Each Item			
			NWN	STA	Cuisenaire	Total
1	10	Line AB longer	56.7	33.3	45.0	45.0
		Line CD longer	10.0	15.0	15.0	13.3
		Lines AB and CD same	33.3	51.7	40.0	41.7
2	11	Strip EF longer	43.3	28.3	30.0	33.9
		Strip GH longer	16.7	18.3	35.0	23.3
		Strips EF and GH same	40.0	53.3	35.0	42.8
	12	Strip EF longer	36.7	21.7	35.0	31.1
		Strip GH longer	28.3	35.0	30.0	31.1
		Strips EF and GH same	35.0	43.3	35.0	37.8
	13	Strip EF longer	36.7	18.3	35.0	30.0
		Strip GH longer	26.7	41.7	40.0	36.1
		Strips EF and GH same	36.7	40.0	25.0	33.9

Line AB unmoved - Line CD altered to form an acute angle.

Strip EF uncut - Strip GH cut several times.

In the second part, all the children were quite certain that the two strips of paper were equal in length. After the first cutting, the number was quickly reduced to 42.8 per cent. Subsequent cuttings produced a successive reduction to 37.8 per cent, then to 33.9 per cent in the number of children who were certain that the strips were still the same length. Many children consistently changed their minds depending on the arrangement of the pieces of paper of strip GH. If the pieces happened to be arranged in a "line" which was obviously shorter than strip EF, EF was longer. If the pieces were spread out so that the extremities of line GH projected beyond those of strip EF, the children changed their minds.

The opposite arrangement resulted in a similar procedure. Those children who could not conserve in this part of the test were really concentrating on the ends of the "lines". The spaces between the pieces of paper or the overlapping of the pieces did not apparently concern them.

The results of this subtest favored substantially the STA representatives. Their superior achievement may be attributed to certain measuring activities which form an integral part of this series' grade one arithmetic program. Exercises such as the placing, end to end, of sticks or pieces of cardboard to objects of varying lengths can be found in STA workbooks.

Results of Subtest V - Measurement of Length

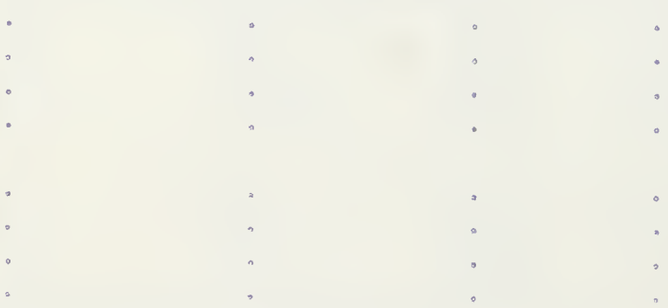
This subtest was devised to determine how many of these children could measure when confronted with measuring units not familiar to them. Again this test was divided into two parts. The first part was designed to determine the child's ability to compare, without the use of standardized units, various shapes as to their equality or inequality. Each child was asked three questions and the resulting answers were scored. In the second part the children were required to use unmarked measuring linear units to verify each of their appraisals which were scored. Table XII shows the distribution of scores.

TABLE XII

SUMMARY OF SCORES OF SUBTEST V

Part	Scores	Per Cent of Children Achieving Score			
		NWN	STA	Cuisenaire	Total
1	3	5.0	8.3	5.0	6.1
	2	6.7	11.7	0.0	6.1
	1	15.0	8.3	10.0	11.1
	0	73.0	71.7	85.0	76.6
2	3	3.3	10.0	5.0	6.1
	2	1.7	1.7	0.0	1.1
	1	5.0	10.0	5.0	6.7
	0	90.0	78.3	90.0	86.1

The majority (about seventy-six per cent) of the grade one children was not able to estimate the equality or



inequality of these shapes. Further they were generally unable to make adequate use of the unmarked linear units. In the first part, the shape with the longest arm was invariably selected as being longer. In item fourteen 73.3 per cent of the children chose the shape with the longer arm. In item fifteen, 86.7 per cent of the children selected the shape with the longer arm. In item sixteen, 84.2 per cent of the children singled out the shape with the longer arm. Only 6.1 per cent of the children thought that each pair of shapes was equal in length. Few children were able to concentrate on all four arms of pair of shapes at one time. The second part of the test produced similar results. Only 6.1 per cent of the children could successfully use the linear units. Of the balance 7.8 per cent had some notion while 86.1 per cent could not even make a beginning.

Further inspection of Table XII revealed that the STA sample displayed a slight superiority over the performance of the other children in this subtest. This apparent advantage should not be misconstrued as implying that STA's better treatment of measurement was solely responsible since a large number (about three-fourths) of its representatives in this study was completely unsuccessful. A closer scrutiny of the 6.1 per cent who were successful disclosed that the typical candidate was a boy with low socio-economic status

and high mental ability. Arithmetic program was not the determining factor.

The majority (76.6 per cent for the first part and 86.1 per cent for the second part) were unable to cope with the demands of this subtest. Obviously they were not ready at this point in their development to undertake measuring activities which involved the use of standard units.

Results of Subtest VI - Subdividing a Straight Line

This subtest was designed to determine the child's ability to measure spontaneously when he is confronted with a variety of measuring situations. It consisted of two twenty-inch rods with a bead on each that was free to move. The linear units used were considered standardized for the purposes of this subtest. Total possible score was six. A distribution of scores is shown in Table XIII.

TABLE XIII

SUMMARY OF SCORES OF SUBTEST VI

Scores	Per Cent of Children Achieving Score			
	NWN	STA	Cuisenaire	Total
6	0.0	6.7	5.0	3.9
5	0.0	0.0	0.0	0.0
4	1.7	1.7	0.0	1.1
3	0.0	1.7	0.0	0.6
2	3.3	0.0	0.0	1.1
1	68.3	50.0	65.0	61.1
0	26.7	39.9	30.0	32.2

few children were equal to the requirements of this subtest. A relatively small number (3.9 per cent) of all the children successfully subdivided a straight line. Interestingly this percentage represents five children all of whom were judged to possess high mental ability. Of the five, four had been exposed to the STA text and the other had been instructed by the Cuisenaire method. A score of four was the best result obtained by one child who had had experience with the NWN series. Of the remainder, approximately two-thirds managed only a score of one (realized principally as a result of item twenty, the first requisite of this subtest) while slightly less than one-third did not or could not respond to the questioning.

More detailed results are shown in Table XIV.

Although standardized units were provided and the children were urged to use them, it was possible for the children, in item twenty, to manipulate correctly the objects by making a visual estimation. After the investigator had moved his bead a short distance from the left, a child could simply move his bead on his rod an equal distance from the left also without reference to the units provided. Such a child visually aligned his bead with that of the investigator. Of the 66.1 per cent who managed to align their bead, 31.7 per cent attempted to verify their first appraisal by placing one of the standardized units across and perpendic-

ular to the two wires alongside the two beads. Some (12.1 per cent) of the children, who had unsuccessfully estimated, tended to move their bead a distance less than the investigator's. Subsequent manipulations however required some form of measurement. It is evident from an examination of the results of the succeeding subtest items that the majority (about ninety-five per cent) of these grade one children could not subdivide a straight line.

TABLE XIV

SUMMARY OF RESULTS OF SUBTEST VI

Item	Activity	Per Cent Response for Each Item			
		NWN	STA	Cuisenaire	Total
20	Correctly moved the bead	71.7	61.7	65.0	66.1
	Didn't or couldn't	28.3	38.3	35.0	33.9
21	Correctly moved the bead	0.0	10.0	5.0	5.0
	Didn't or couldn't	100.0	90.0	95.0	95.0
22	Correctly moved the bead	0.0	10.0	5.0	5.0
	Didn't or couldn't	100.0	90.0	95.0	95.0
23	Correctly moved the bead	6.7	10.0	5.0	7.2
	Didn't or couldn't	93.3	90.0	95.0	92.8
24	Correctly moved the bead	1.7	8.3	5.0	5.0
	Didn't or couldn't	98.3	91.7	95.0	95.0
25	Correctly moved the bead	1.7	10.0	5.0	5.6
	Didn't or couldn't	98.3	90.0	95.0	94.4

In item twenty-three, 52.5 per cent of the children understandingly moved their bead by making a visual estima-

tion. Surprisingly 39.2 per cent refused to move their bead. Since the two beads were already aligned they were quite certain that the two beads were the same distance from the left. One of these children exclaimed: "That's a tricky one!" It is quite apparent that a large number of these grade one children could only concentrate on one aspect of the test at one time ignoring other significant factors. In this instance these children were not taking into account the arrangement of the two wires. Other findings in this subtest substantiate this fact. For instance, as a result of requested manipulation in items twenty-one, twenty-two, twenty-four and twenty-five almost half (44.2 per cent) of the children simply moved their bead from either the right or left end until it was aligned with the investigator's bead.

One child refused to manipulate any part of the instrument in this subtest.

Graphical Representation of Subtest Achievement

To provide a comparative picture of the performances of the children tested a graphical representation of their total achievement scores on each subtest is given in figures one, two and three.

Figure one, representing a profile of the percentage of children who had performed on the subtests successfully, points to the fact that, except for subtest II, where the

NWN children displayed a slight superiority, the STA students were, as a group, consistently better. No reason can be advanced for the differences in subtest II. Peak performance was obtained in subtest IV A after which there was a rapid decrease in the number of children who could manipulate the objects of the test and who could provide logical reasons for their responses. The results of the subtests also revealed the high percentage of children who had acquired some understanding of the concepts the test was determining. Figure II represents this graphical profile. After subtest III the number of children whose notion of measurement was inconclusive dropped sharply. However, the children's performance with the items of subtest VI apparently reversed the trend. This reversal can be attributed to item twenty where the children could and did visually estimate the distance their bead had to be moved. This preliminary step in the development of this subtest did not in itself constitute an understanding of the ideas relevant to subdividing a straight line. Furthermore, the proportion of Cuisenaire children who had a partial understanding of measurement was often greater than that of either the NWN or STA children. From an analysis of the subtest means calculated for each arithmetic program and represented in figure three, the following can be deduced: 1) the slight superiority of the STA children throughout the test; 2) the peak

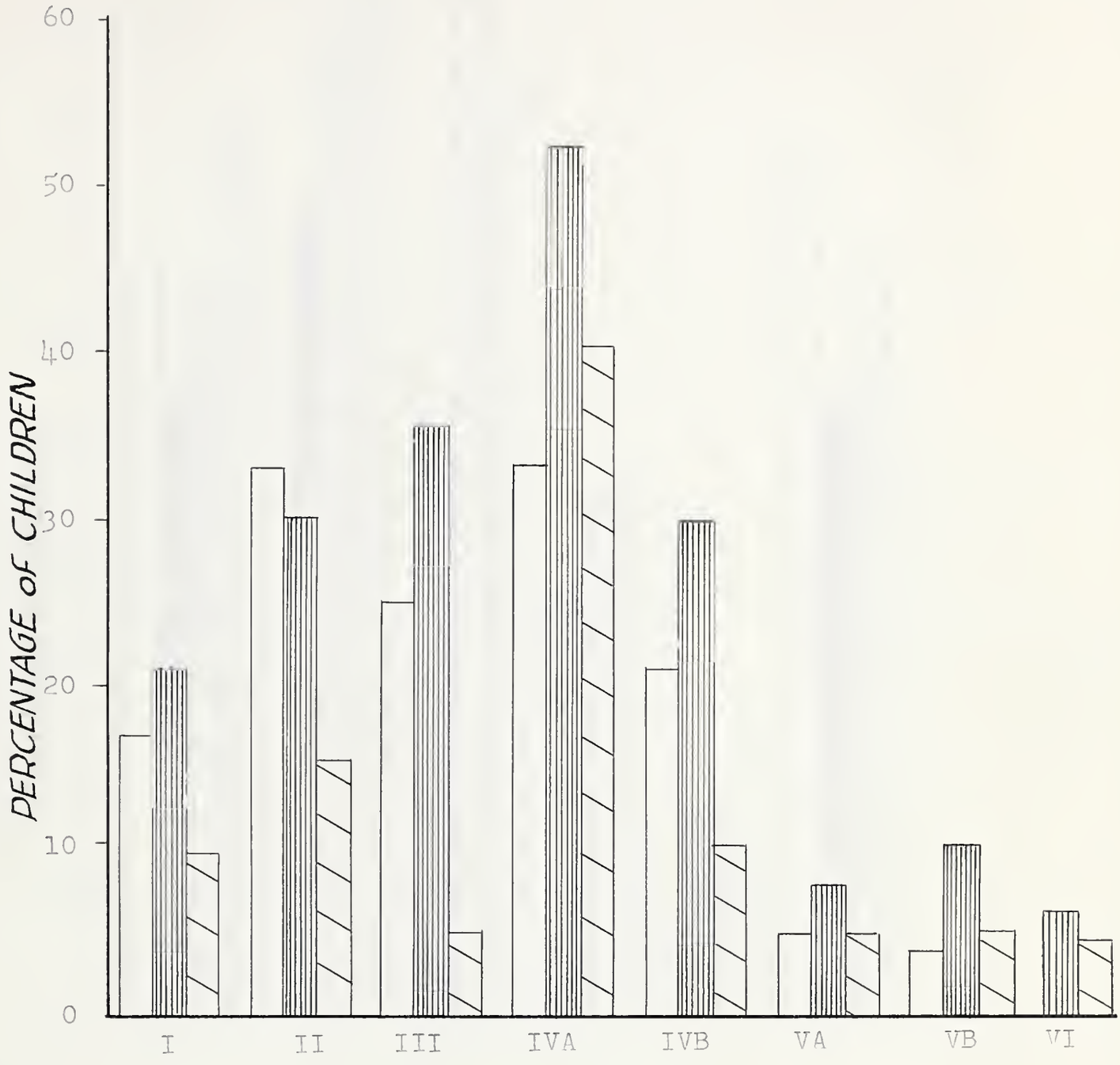


FIGURE I

PERCENTAGE OF CHILDREN WHO OBTAINED A PERFECT SCORE ON EACH SUBTEST (NWN REPRESENTED BY WHITE BARS, STA BY LINED BARS AND CUISENAIRE BY STRIPED BARS)

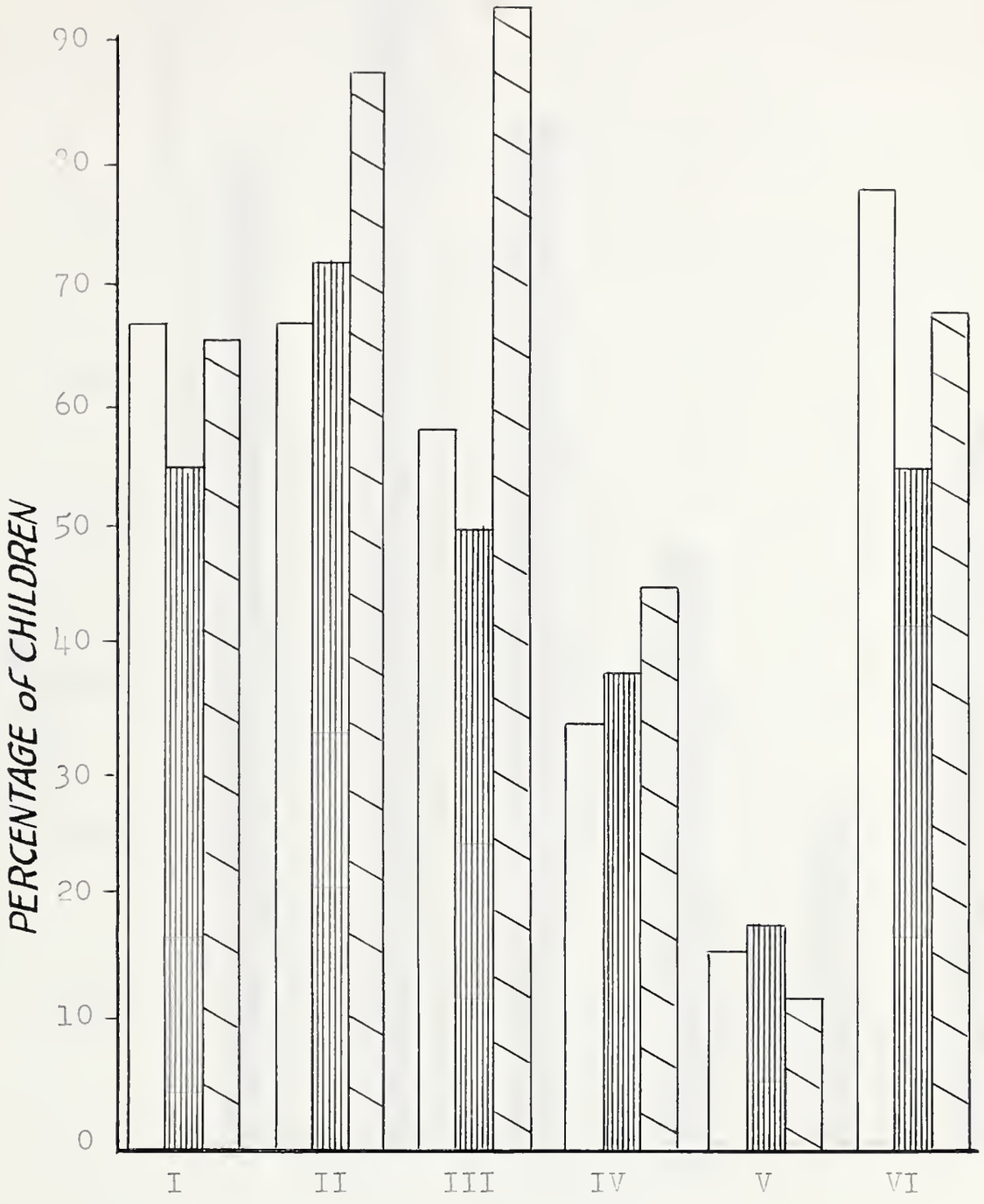


FIGURE 2

PERCENTAGE OF CHILDREN WHO OBTAINED PART SCORE ON EACH SUBTEST (NWN REPRESENTED BY WHITE BARS, STA BY LINED BARS AND CUISENAIRE BY STRIPED BARS)

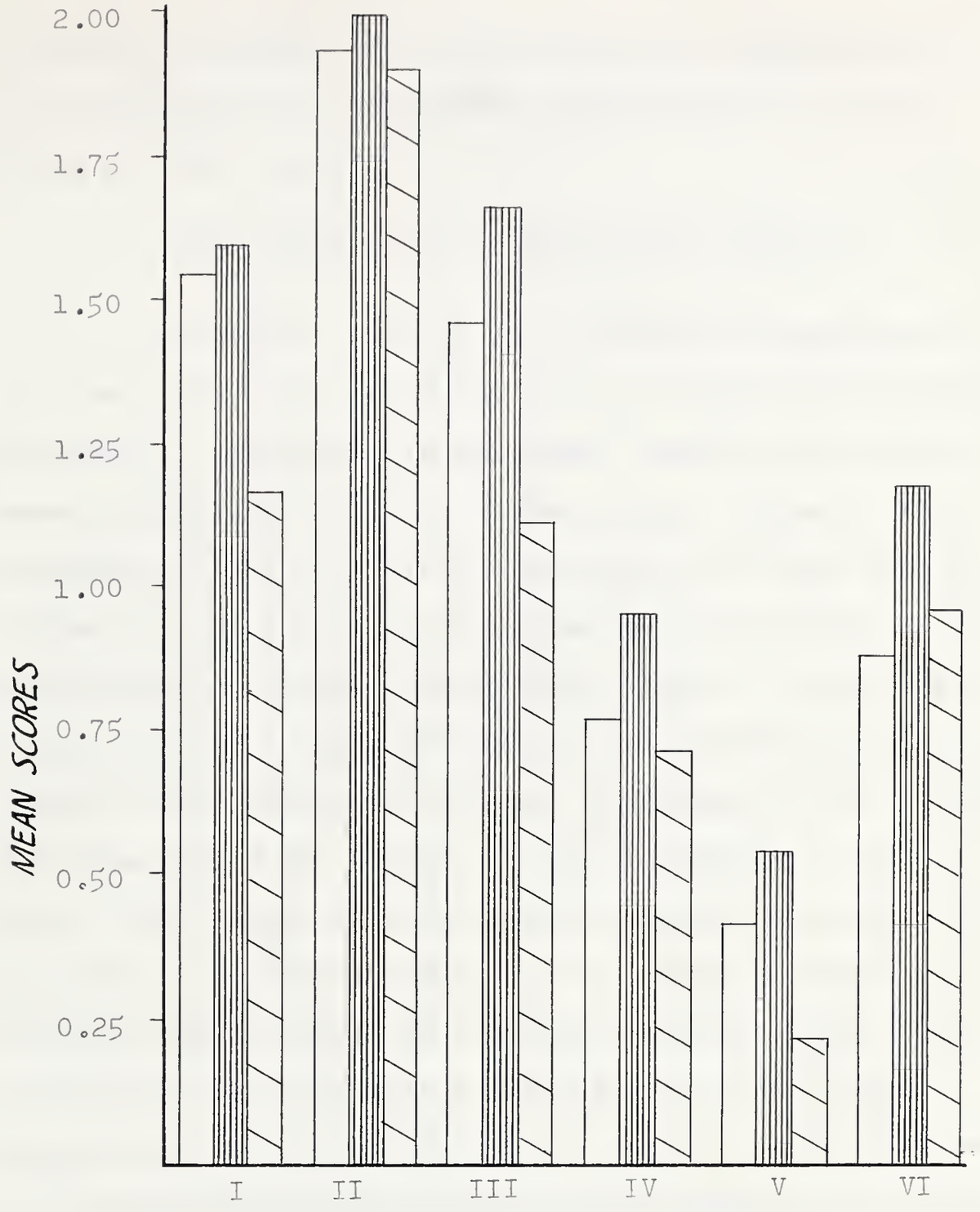


FIGURE 3

MEAN SCORES FOR EACH SUBTEST BASED ON DATA OBTAINED FROM THE SUMS OF SCORES FOR SUBTESTS I TO VI (NWN REPRESENTED BY WHITE BARS, STA BY BLACK BARS AND CUISENAIRE BY STRIPED BARS)

realized in subtest II; 3) the decreasing understanding of the concepts the subtests were determining; 4) the low means for each subtest.

III. DISCUSSION OF STATISTICAL ANALYSIS

To provide a basis for the statistical analysis of the test data, a two by three by two by two matrix (as shown in Table II, page 35) was developed from the total test scores of all the children in the sample. Since 1) the frequency (five) of each cell was small, 2) there were no uneven cell frequencies, 3) the sample was relatively small (N=120) and the level of each factor (sex: boy or girl; mental ability: high, medium or low; socio-economic status: high or low; arithmetic program: NWN series or STA series) was also small, the testing of the simultaneous effect of these four factors could be best accomplished by submitting this data to a four-way analysis of variance. This type of analysis was developed by interpolating from Winer's[9] description of computational procedures for three-factor experiments. Matrics depicting the sums of total test scores of subsequent interactions are shown in Tables XXI to XXXVI inclusive (See Appendix B). Table XV summarizes the calculations for the analyses of variance of the fifteen possible

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[9]B. J. Winer, Statistical Principles in Experimental Design (New York: McGraw Hill Book Company, 1962), pp. 228-257.

combinations of interacting factors. The summary of the experimental F test results for each variation of the combining factors is shown in Table XVI. Examination of the test results revealed that differences in mental ability influence significantly the development of the concepts of linear measurement in grade one children. It can not be inferred from this conclusion that grade one children with high mental ability would necessarily acquire these concepts more readily than grade one children with medium mental ability and similarly that young children with medium mental ability would gain an understanding of these ideas more easily than children with low mental ability. In order to analyse these differences more closely it was decided to submit the relevant data to t tests of significance. Table XVII summarizes the calculations and results.

For reasons stated in chapter three the Cuisenaire group constituted a subsidiary sample. As a consequence it could not be included in the analysis of the central problem. To provide a statistical comparison of the test results of the three arithmetic programs it was decided to submit the data to t tests of significance. Table XVIII summarizes the relevant calculations and results. A summary of the means and standard deviations calculated for each level of each factor is shown in Table XIX.

TABLE XV

SUMMARY OF THE CALCULATIONS FOR THE ANALYSES OF VARIANCE
N=120

Source of Variation	Sum of Squares	Degrees of Freedom	Variance Estimate
Sex	.075	1	.075
Mental Ability	123.717	2	61.859
Socio-economic Status	5.209	1	5.209
Arithmetic Program	38.009	1	38.009
Sex and Mental Ability	23.550	2	11.775
Mental Ability and Socio-economic Status	35.816	2	17.908
Mental Ability and Arithmetic Program	19.116	2	9.558
Socio-economic Status and Arithmetic Program	16.674	1	16.674
Sex and Arithmetic Program	17.341	1	17.341
Sex and Socio-economic Status	12.775	1	12.775
Mental Ability, Socio-economic Status and Arithmetic Program	98.241	2	49.121
Sex, Socio-economic Status and Arithmetic Program	14.342	1	14.342
Sex, Mental Ability and Arithmetic Program	81.484	2	40.742
Sex, Mental Ability and Socio-economic Status	26.450	2	13.225
Sex, Mental Ability, Socio-economic Status and Arithmetic Program	61.183	2	30.592
Within cell	1346.000	96	14.020
Total	1919.792	119	

TABLE XVI

SUMMARY OF F TEST RESULTS $\alpha = .05$
N=120

Source of Variation	Degrees of Freedom: Variation	Degrees of Freedom: Within Cell	F-Ratio: Calculated	F-Ratio: Required* from Tables	Concluded Differences
Sex, Mental Ability, Socio-economic Status and Arithmetic Program	2	96	2.182	3.094	not significant
Sex, Mental Ability, and Socio-economic Status	2	96	0.943	3.094	not significant
Sex, Mental Ability and Arithmetic Program	2	96	2.906	3.094	not significant
Sex, Socio-economic Status and Arithmetic Program	1	96	1.023	3.944	not significant
Mental Ability, Socio-economic Status and Arithmetic Program	2	96	3.504	3.094	significant
Sex and Mental Ability	2	96	0.840	3.094	not significant
Sex and Socio-economic Status	1	96	0.911	3.944	not significant
Sex and Arithmetic Program	1	96	1.233	3.944	not significant
Mental Ability and Socio-economic Status	2	96	1.277	3.094	not significant
Mental Ability and Arithmetic Program	2	96	0.681	3.094	not significant
Socio-economic Status and Arithmetic Program	1	96	1.189	3.944	not significant
Sex	1	96	0.005	3.944	not significant
Mental Ability	2	96	4.412	3.094	significant
Socio-economic Status	1	96	0.372	3.944	not significant
Arithmetic Program	1	96	2.711	3.944	not significant

*G. A. Ferguson, Statistical Analyses in Psychology and Education (New York: McGraw-Hill Book Company Inc., 1959), pp. 310-313.

TABLE XVII

SUMMARY OF THE RESULTS OF
MENTAL ABILITY WITH
t TESTS
N=120

Source of Variation	Degrees of Freedom	t* critical	t calculated	Concluded Differences
High Mental Ability and Medium Mental Ability	78	1.994	1.154	not significant
High Mental Ability and Low Mental Ability	78	1.994	3.376	significant
Medium Mental Ability and Low Mental Ability	78	1.994	2.129	significant

*G.A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill Book Company, 1959), p. 308.

TABLE XVIII

SUMMARY OF THE RESULTS OF
ARITHMETIC PROGRAM WITH t TESTS
N=140

Source of Variation	Degrees of Freedom	t* critical	t calculated	Concluded Differences
NWN and STA	118	1.981	1.791	not significant
NWN and Cuisenaire	78	1.994	0.915	not significant
STA and Cuisenaire	78	1.994	1.858	not significant

*G. A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill Book Company, 1959), p. 308.

TABLE XIX

SUMMARY OF THE MEANS AND STANDARD DEVIATIONS CALCULATED FOR EACH LEVEL OF EACH FACTOR (SEX, MENTAL ABILITY, SOCIO-ECONOMIC STATUS AND ARITHMETIC PROGRAM) N=140

		Means	Standard Deviations
Sex	Boy	8.25	4.272
	Girl	8.33	3.780
Mental Ability	High	9.63	4.383
	Medium	8.50	4.137
	Low	6.75	3.118
Arithmetic Program	NWN	7.78	3.273
	STA	9.13	4.571
	Cuisenaire	6.95	3.706
Socio-economic Status	High	8.25	3.671
	Low	8.33	4.356

Effect of Sex on the Development of Concepts of Linear Measurement

In an attempt to determine the effect of sex on the development of concepts of linear measurement in grade one children it was possible to isolate these results as shown in Table XXXII. The sum of the total test scores favored the girls by three points. An examination of Table XVI

reveals that this difference is not significant. Further the various interactions of sex with mental ability, socio-economic status and arithmetic program also produced results which were not significant.

Effect of Mental Ability on the Development of Concepts of Linear Measurement

To ascertain the effect of mental ability on tests with a high degree of manipulative content, the principal sample of one hundred twenty children was grouped into three levels of mental ability; that is, high, medium or low mental ability. Sums of test scores are shown in Table XXXIII. A study of Table XVI reveals that there is a significant difference in the development of concepts of linear measurement of grade one children. Results of t tests of significance at the .05 level of significance as shown in Table XVII further substantiate these findings. The performance on the tests of children with high mental ability was significantly better than the performance of children with low mental ability. Similarly the children with medium mental ability performed significantly better than the children with low mental ability. However no significant difference could be established between the performance of children with high mental ability and those of medium mental ability. A further examination of Table XVI reveals that the various factors

interacting with mental ability generally produced differences which were not significant. However, the combination of mental ability, socio-economic status and arithmetic program resulted in the only other source of variation which was significant. Cell means for each possible source of interaction were calculated and are shown in Table XX. As suggested by Ferguson,[10] the comparison of two means at a time using a t test following an F test could reveal that differences between certain pairs of means may be significant while others may not. Differences between the three levels of mental ability have already been discussed and will not be repeated. In the application of the t test the within-cell variance estimate of 14.020 was utilized. The value required for significance at the .05 level with ninety-six degrees of freedom was 1.988.

It is evident from an examination of Table XX that sizable differences existed between the mean of low socio-economic status and STA and the other three high mental ability means. Applying the t test successively to each pair to compare the former mean with each of the latter disclosed that the mean of high mental ability, low socio-economic status and STA when compared with 1) high mental

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[10] G.A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill Book Company, 1959), p. 238.

TABLE XX

CELL MEANS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH THREE-WAY CLASSIFICATION (MENTAL ABILITY, SOCIO-ECONOMIC STATUS AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

	NWN		STA	
	High Socio-Economic Status	Low Socio-Economic Status	High Socio-Economic Status	Low Socio-Economic Status
High Mental Ability	9.2	8.3	8.2	12.8
Medium Mental Ability	7.2	8.8	9.8	8.6
Low Mental Ability	6.3	6.9	8.8	6.6

ability, high socio-economic status and STA, t was calculated to be 2.740; 2) high mental ability, high socio-economic status and NWN, t was calculated to be 2.144; and 3) high mental ability, low socio-economic status and NWN, t was calculated to be 2.680. Each comparison produced differences that were statistically significant. Further application of the t test to similar pairs of means did not produce differences that were significant. From the evidence submitted it would appear that the interaction of socio-economic status,

arithmetic program and high mental ability was responsible for the three factors: mental ability, socio-economic status and arithmetic program to produce differences that were significant.

Effect of Socio-Economic Status on the Development of Concepts of Linear Measurement

What effect does socio-economic status have on the development of concepts of linear measurement of grade one children? To determine the effect, half of the main sample was designated as of high socio-economic status and half as of low socio-economic status. Sums of test scores are shown in Table XXXIV. The scores of the children representing the low socio-economic status group were slightly better than the scores of the high socio-economic status group. However, the difference is not significant as shown in Table XVI. Except for the situation mentioned in the previous section, there were no interactions involving socio-economic status which were significant.

Effect of Arithmetic Program on the Development of Concepts of Linear Measurement

The three arithmetic series used in this study differed basically in their treatment of measurement. NWA exposed the grade one children to a series of exercises

designed to make the children familiar with common measuring devices such as the thermometer and with simple monetary transactions. STA, in addition, incorporated into its grade one program hierarchically arranged exercises which stressed some aspects of linear measurement. In contrast, the Cuisenaire method of arithmetic instruction did not contain specific measurement activities or exercises. Test scores are shown in Table XXXV. Although these scores favor the children who had been exposed to the STA series, Table XVI reveals that these differences are not significant. A further analysis of the results in Table XVIII substantiates this finding. However it must be noted that the differences are approaching significance in favor of the STA group.

Except for the difference mentioned earlier, arithmetic program in conjunction with other factors produced differences which were not significant.

IV. SUMMARY OF FINDINGS

Findings Related to the Hypotheses

Hypothesis 1. There is no significant difference in the development of the basic concepts of linear measurement between grade one boys and grade one girls.

The hypothesis is accepted.

Hypothesis 2. There is no significant difference in the development of the basic concepts of linear measurement

between grade one children of high mental ability, medium mental ability and low mental ability.

The hypothesis is rejected. It was found that the children with high mental ability were more advanced in their development of the concepts of linear measurement as measured by this test than the children with low mental ability. A similar condition was found to exist between the children possessing medium mental ability and the children of low mental ability. The differences that were found to exist between the children of high mental ability and those of medium mental ability were judged to be not significant.

Hypothesis 3. There is no significant difference in the development of the basic concepts of linear measurement between grade one children of high socio-economic status and grade one children of low socio-economic status.

The hypothesis is accepted.

Hypothesis 4. There is no significant difference in the development of the basic concepts of linear measurement between grade one children who had been exposed to the NWN arithmetic program, grade one children who had been exposed to the STA arithmetic program and grade one children who had been instructed by the Cuisenaire method.

The hypothesis is accepted.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this investigation was to determine to what extent grade one children's conception of linear measurement had developed. To trace the development of this particular concept, a test was constructed by this investigator. It consisted of six subtests each designed to analyse the children's conceptual understanding of the conservation of distance, the conservation of length, spontaneous and provoked measurement and the subdivision of a straight line. These subtests were administered individually to one hundred forty grade one children.

The sample was selected from 799 grade one children attending eleven city of Edmonton Public Schools in June 1964. These schools were judged to be representative of three socio-economic levels. The main sample consisted of: thirty boys and thirty girls who had received arithmetic instruction from the NWN series and thirty boys and thirty girls who had used the STA series. Intelligence, as an interacting factor, was also considered. The two groups were matched according to high, medium or low mental ability. In addition, a subsidiary experiment was conducted with eight boys and twelve girls who had been instructed by the Cuisenaire method.

This study was limited to the population of grade one children in the city of Edmonton Public Schools and the sample selected was deemed to be representative of this population.

The test was administered by the investigator during the month of June, 1964, after the children had received about nine months of formal arithmetic instruction. The tests were scored and the results analysed by submitting the data to a four-way analysis of variance. To assist in the evaluation of some findings t tests were administered to certain data. Hence, the following hypotheses were tested at the five per cent level of significance.

Hypothesis 1

There is no significant difference in the development of the basic concepts of linear measurement between grade one boys and grade one girls.

Hypothesis 2

There is no significant difference in the development of the basic concepts of linear measurement between grade one children of high mental ability, medium mental ability and low mental ability.

Hypothesis 3

There is no significant difference in the development of the basic concepts of linear measurement between grade

one children of high socio-economic status and grade one children of low socio-economic status.

Hypothesis 4

There is no significant difference in the development of the basic concepts of linear measurement between grade one children who had been exposed to NWM, grade one children who had been exposed to STA and grade one children who had had Cuisenaire instruction.

I. CONCLUSIONS

From the results of this study it may be concluded:

1. No significant difference was found to exist in the development of the basic concepts of linear measurement between grade one boys and grade one girls. Hence it would appear that sex is not a contributing factor in the acquisition of these concepts.
2. The development of the concepts of linear measurement is not affected by differing socio-economic levels. Although the children from low socio-economic homes displayed a very slight superiority over the children from high socio-economic homes, the differences, however, were found to be not significant. It would seem that differences in the development of these concepts in children at this maturation level can be attributed to factors other than solely environment.
3. Children with high and with average mental ability were

found to be clearly superior in their understanding of linear measurement to children possessing low mental ability. It can not be inferred that the children with the higher mental abilities had mastered the relevant concepts. The results only indicated that, although no child in the sample had achieved complete understanding of the concepts of linear measurement, children with higher mental capacity were more advanced in their development than the children with low mental capacity. Differences between high mental ability and average mental ability were found to be not significant in spite of the fact that the test results favored the higher mental ability group.

4. The development of the concepts of measurement in grade one children was not affected by the arithmetic program to which they had been exposed. Whatever differences occurred among the three programs, these were found to be not significant.

It must be kept in mind that at the five per cent level no significant differences were found between the mean scores in the different arithmetic programs. However the mean scores of the pupils in the STA program produced a difference that was approaching significance in relation to the other programs.

5. The mere fact that young children are able to verbalize measurement terms or can identify measuring instruments is

no assurance that they comprehend the underlying concepts. The terms "distance", "length", "measure" were frequently and spontaneously employed by the children in their explanatory responses to the test problems. Their replies and the manipulation of the instruments revealed that they, generally, did not fully understand the significance of the terms.

6. The children's performance on tests dealing with the conservation of length displayed much uncertainty. This property constantly changed. They tended to concentrate on the extremities of the objects which were being compared. For instance in subtest II all the children were aware of the fact that the string was longer than the stick. Yet when the string was returned to its original position, that is, the ends of the stick and string coincided, more than two-thirds of the children stated that the string and the stick were the same length. Few grade one children successfully conserved length.

7. Recognition of the two ten-rods (subtest III) by the Cuisenaire children did not ensure conservation of the lengths of the rods. The Cuisenaire method of arithmetic instruction attaches a number to a unit length: the concept of one is represented by a rod one centimeter in length, the concept of two is represented by a rod two centimeters in length, and so on. Length is associated with number. The

rods are number symbols. In manipulating rods the children are manipulating number symbols. It is recognized, however, that number is independent of the physical characteristics of the objects represented. When the child understands this independence we assume he has acquired the true concept of number. In Cuisenaire instruction the symbol tends to retain certain physical properties which can be erroneously associated with number in the mind of the child.

II. IMPLICATIONS

The findings of this study give rise to some implications for educational practice.

1. It would appear that the continued inclusion of measurement as an integral part of the arithmetic curriculum of the early school years is dependent on a logical system of systematically and sequentially arranged activities. Because of the wide variations in children's basic understanding of these concepts, writers of arithmetic texts must be cognizant of the fact that even the simplest ideas relevant to measurement may not be known by a significant proportion of young children.

2. The mere inclusion of activities and practices involving the use of tables of measures and measuring devices does not constitute an effective measurement program. Further the correct manipulation of these measuring facts can not pass

for understanding of the underlying concepts.

3. It would seem that an understanding of the concepts of distance and length is basic to linear measurement. From this children should be able to proceed to crude measuring activities in situations familiar to them. From such practices the need for standardized units should arise.

4. Because of the great variety in children's pre-school experience, different kinds of activities for children of different levels must be incorporated into arithmetic programs. Through in-service education teachers must be made aware of the conceptual development of the measurement process and be provided with the necessary background to adapt their methods in order to meet the needs of individual students.

III. RECOMMENDATION AND SUGGESTIONS FOR FURTHER RESEARCH

Should measurement experiences and activities be incorporated into a grade one arithmetic program? Or, should the teaching of these ideas be postponed to a later grade? It would seem, from the findings of this study, that grade one children are not ready to assimilate concepts relevant to an understanding of linear measurement. It is felt that a conceptual understanding of number precedes the acquisition of concepts of linear measurement. The child must first

acquire a working knowledge of number because measurement is dependent for its development on such properties of number as one-to-one correspondence, cardinality and ordinality. Therefore it would appear that measurement has inherent difficulties which most children can not understand at the grade one level. The treatment of linear measurement as an integral part of the elementary arithmetic program should be delayed. With more mature children these ideas can be dealt with more easily and more economically.

This study, in an attempt to discover grade one children's conception of linear measurement, has revealed some areas for further study.

1. It was found that differences in socio-economic status were not a significant contributing factor in the development of concepts of linear measurement. Is this phenomena peculiar to the development of this concept? There is ample evidence from research to support the contention that knowledge is influenced by differing environment. More research is needed to investigate this apparent contradiction.
2. Further research, perhaps could determine the exact nature of a child's understanding of such terms as distance, length, measure, and so on. Comprehension can not be determined solely by verbalization.
3. If the concepts underlying the development of linear measurement were taught to young children, what would be the

effect on the development of an operational idea of measure? Should children be allowed to make comparisons in measures over a longer period of time? What is the most effective way of fostering some of the basic concepts of measures? What kind of concrete and manipulative materials is most appropriate? These and related questions need to be studied.

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APPENDIX A

A TEST FOR MEASUREMENT READINESS

Subtest I. Reconstructing Relations of Distance

(Materials: two five inch dolls, one four and half inch can, one screen twelve by eight inches, one cube two by three by twelve inches.)

1. Place the two dolls facing each other twenty-five inches apart. Place doll (B) on the can.

Is it farther from this doll (A) to that doll (B) or is it farther from that doll (B) to this doll (A) or is it the same?

Are the dolls near or far apart?

2. Place the screen between the dolls.

Are the dolls closer together now, farther apart now or are they the same as they were before?

How do you know?

3. Remove the screen and place the cube between the dolls.

Are the dolls closer together now, farther apart now or are they the same as they were before?

How do you know?

Subtest II. Conservation of Length

(Materials: one ten inch stick, one piece of string fifteen inches long.)

4. Place the stick and an undulating piece of string

side by side on a table so that their extremities coincide.
Tell me which is longer, the stick or the piece of string or are they both the same.
How do you know?

5. Extend the piece of string.
Tell me which is longer, the stick or the piece of string or are they both the same.
How do you know?

6. Return the string to its original shape (as in item four).
Tell me which is longer, the stick or the piece of string or are they both the same.
How do you know?

Subtest III. Conservation of Length with a Change of Position

(Materials: two four inch rods.)

Place the two rods side by side on a table with their extremities coinciding.
Tell me which stick is longer or are they both the same.
How do you know?

7. Push the rod closer to the child about half an inch to left.
Tell me which stick is longer or are they both the same.
How do you know?

8. Arrange the rods to form the letter T.

Tell me which stick is longer or are they both the same.

How do you know?

9. Arrange the rods to form an acute angle.

Tell me which stick is longer or are they both the same.

How do you know?

Subtest IV. Conservation of Length with Distortion of Shape

(Materials: twelve counting sticks, two strips of paper each fourteen inches long and half an inch wide, one pair of scissors.)

Arrange the counting sticks into two parallel lines of six counting sticks each about one inch apart. The two lines must be aligned.

Tell me which line of sticks is longer or are they both the same.

How do you know?

10. Rearrange the line of sticks closer to the child to form a right angle. Break two sticks.

Tell me which line of sticks is longer or are they both the same.

How do you know?

Place the two strips of paper side by side with their extremities coinciding.

Tell me which strip of paper is longer or are they both the same.

How do you know?

11. Cut the strip of paper closer to the child into about two equal pieces.

Now which is longer, these two pieces of paper together or this strip of paper (uncut) or are they both the same?

How do you know?

12. Cut at an angle one of the two pieces cut previously in item eleven.

Now which is longer, these three pieces of paper together or this strip of paper (uncut) or are they both the same?

How do you know?

13. Cut at an angle the other of the two pieces (in item twelve).

Now which is longer these four pieces of paper together or this strip of paper (uncut) or are they both the same?

How do you know?

Subtest V. Measurement of Length

(Materials: a quantity of unmarked cardboard strips each half inch wide and two inches, four inches or six inches long; three hardboards equal in size and measuring fourteen by eighteen inches with the following pairs of half inch wide figures pasted on each--the first pair of figures consisted of two right angles, one with arms two and six inches long, the other with both arms four inches long. The second

pair of figures consisted of an obtuse angle with a fourteen-inch arm and a two-inch arm and an acute angle having a six-inch arm and a ten-inch arm. The third pair of figures consisted of a V-shaped acute angle having arms both equal to twelve inches and an obtuse angle having arms eight inches long and sixteen inches long.)

14. Show the first pair of lines.

Tell me which line is longer or are they both the same.

How do you know?

15. Show the second pair of lines.

Tell me which line is longer or are they both the same.

How do you know?

16. Show the third pair of lines.

Tell me which line is longer or are they both the same.

How do you know?

17. Show the first pair of lines.

Place any of these pieces of cardboard on these two lines to see if one line is longer or if they are the same.

How do you know?

18. Show the second pair of lines.

Place any of these pieces of cardboard on these two lines to see if one line is longer or if they are the same.

How do you know?

19. Show the third pair of lines.

Place any of these pieces of cardboard on these lines to see

if one line is longer or if they are the same.

How do you know?

Subtest VI. Subdividing a Straight Line

(Materials: two straight twenty inch rods each with a bead that is free to move along it, three sticks measuring three inches, ten inches and thirty inches.)

The child faces the two wires.

20. Place the two wires in exact alignment with the two beads at the extreme left, that is, the child's left.
Take your bead and put it as far from this end (left) as I am going to put mine from this end (left).
I take my bead and put it this far (about four inches).
I want you to do the same.

21. Place the two wires in exact alignment with one bead at the extreme left and the other at the extreme right.
Take your bead and put it as far from this end (right) as I am going to put mine from this end (left).
I take my bead and put it this far (about four inches).
I want you to do the same.

22. Place the two wires in exact alignment with one bead at the extreme left and the other at the extreme right.
Take your bead and put it as far from this end (right) as I am going to put mine from this end (left).
I take my bead and put it this far (a little more than ten inches).

I want you to do the same.

23. Push the wire farthest from the child about four inches to the left.

Place the two beads at the extreme left of the wires.

Take your bead and put it as far from this end (left) as I am going to put mine from this end (left).

I take my bead and put it this far (about four inches).

I want you to do the same.

24. Leave the wires in the same position as for item twenty-three. Place one bead at the extreme left of one wire and the other bead at the extreme right of the other wire.

Take your bead and put it as far from this end (right) as I am going to put mine from this end (left).

I take my bead and put it this far (a little more than ten inches).

I want you to do the same.

25. Arrange the two wires to form an acute angle so that their extremities are not aligned. Place one bead at the extreme left of one wire and the other bead at the extreme right of the other wire.

Take your bead and put it as far from this end (right) as I am going to put mine from this end (left).

I take my bead and put it this far (more than ten inches).

I want you to do the same.

APPENDIX B

TABLE XVI

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH FOUR-WAY CLASSIFICATION (SEX, MENTAL ABILITY, SOCIO-ECONOMIC STATUS AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

		NWN		STA		
		High Socio-Economic Status	Low Socio-Economic Status	High Socio-Economic Status	Low Socio-Economic Status	Totals
Boy	High Mental Ability	48	38	39	74	199
	Medium Mental Ability	29	38	52	40	159
	Low Mental Ability	40	42	29	37	148
Girl	High Mental Ability	44	45	43	54	186
	Medium Mental Ability	43	50	46	46	185
	Low Mental Ability	23	27	59	29	138
Totals		227	240	268	280	1015

TABLE XXII

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH THREE-WAY CLASSIFICATION (SEX, MENTAL ABILITY, AND SOCIO-ECONOMIC STATUS) WITH FIVE SCORES PER CELL N=120

		High Socio-Economic Status	Low Socio-Economic Status	Totals
Boy	High Mental Ability	87	112	199
	Medium Mental Ability	81	78	159
	Low Mental Ability	69	79	148
Girl	High Mental Ability	87	99	186
	Medium Mental Ability	89	96	185
	Low Mental Ability	82	56	138
Totals		495	520	1015

TABLE XXIII

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH THREE-WAY CLASSIFICATION (SEX, MENTAL ABILITY, AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL
N=120

		HWN	STA	Totals
Boy	High Mental Ability	86	113	199
	Medium Mental Ability	67	92	159
	Low Mental Ability	82	66	148
Girl	High Mental Ability	89	97	186
	Medium Mental Ability	93	92	185
	Low Mental Ability	50	88	138
Totals		467	548	1015

TABLE XXIV

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH THREE-WAY CLASSIFICATION (SEX, SOCIO-ECONOMIC STATUS, AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

	NWN		STA		
	High Socio-Economic Status	Low Socio-Economic Status	High Socio-Economic Status	Low Socio-Economic Status	Totals
Boy	117	118	120	151	506
Girl	110	122	148	129	509
Totals	227	240	268	280	1015

TABLE XXV

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH THREE-WAY CLASSIFICATION (MENTAL ABILITY, SOCIO-ECONOMIC STATUS, AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

	NWN		STA		
	High Socio-Economic Status	Low Socio-Economic Status	High Socio-Economic Status	Low Socio-Economic Status	Totals
High Mental Ability	92	83	82	128	385
Medium Mental Ability	72	88	98	86	344
Low Mental Ability	63	69	88	66	286
Totals	227	240	268	280	1015

TABLE XXVI

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH TWO-WAY CLASSIFICATION (SEX AND MENTAL ABILITY) WITH FIVE SCORES PER CELL N=120

		Totals
Boy	High Mental Ability	199
	Medium Mental Ability	159
	Low Mental Ability	143
Girl	High Mental Ability	186
	Medium Mental Ability	185
	Low Mental Ability	138
Total		1015

TABLE XXVII

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR TWO ANALYSIS OF VARIANCE WITH TWO-WAY CLASSIFICATION (SEX AND SOCIO-ECONOMIC STATUS) WITH FIVE SCORES PER CELL N=120

	High Socio-Economic Status	Low Socio-Economic Status	Totals
Boy	237	269	506
Girl	258	251	509
Totals	495	520	1015

TABLE XVIII

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH TWO-WAY CLASSIFICATION (SEX AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

	NWN	STA	Totals
Boy	235	271	506
Girl	232	277	509
Totals	467	548	1015

TABLE XXIX

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH TWO-WAY CLASSIFICATION (MENTAL ABILITY AND SOCIO-ECONOMIC STATUS) WITH FIVE SCORES PER CELL N=120

	High Socio-Economic Status	Low Socio-Economic Status	Totals
High Mental Ability	174	211	385
Medium Mental Ability	170	174	344
Low Mental Ability	151	135	286
Totals	495	520	1015

TABLE XXX

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH TWO-WAY CLASSIFICATION (MENTAL ABILITY AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL
N=120

	NWN	STA	Totals
High Mental Ability	175	210	385
Medium Mental Ability	160	184	344
Low Mental Ability	132	154	286
Totals	467	548	1015

TABLE XXXI

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH TWO-WAY CLASSIFICATION (SOCIO-ECONOMIC STATUS AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

NWM		STA		
High-Socio-Economic Status	Low Socio-Economic Status	High Socio-Economic Status	Low Socio-Economic Status	Totals
227	240	268	280	1015

TABLE XXXII

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH ONE-WAY CLASSIFICATION (SEX) WITH FIVE SCORES PER CELL N=120

Boy	Girl	Total
506	509	1015

TABLE XXXIII

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH ONE-WAY CLASSIFICATION (MENTAL ABILITY) WITH FIVE SCORES PER CELL
N=120

	Total
High Mental Ability	385
Medium Mental Ability	344
Low Mental Ability	286
Total	1015

TABLE XXXIV

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH ONE-WAY CLASSIFICATION (SOCIO-ECONOMIC STATUS) WITH FIVE SCORES PER CELL N=120

High Socio-Economic Status	Low Socio-Economic Status	Total
495	520	1015

TABLE XXXV

SUMS OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH ONE-WAY CLASSIFICATION (ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

LNM	STA	Total
467	548	1015

TABLE XXXVI

SUMS OF SQUARES OF TEST SCORES OF GRADE ONE CHILDREN FOR THE ANALYSIS OF VARIANCE WITH FOUR-WAY CLASSIFICATION (SEX, MENTAL ABILITY, SOCIO-ECONOMIC STATUS, AND ARITHMETIC PROGRAM) WITH FIVE SCORES PER CELL N=120

		NWN		STA		
		High Socio-Economic Status	Low Socio-Economic Status	High Socio-Economic Status	Low Socio-Economic Status	Totals
Boy	High Mental Ability	520	382	419	1192	2513
	Medium Mental Ability	189	328	584	516	1617
	Low Mental Ability	322	394	181	317	1214
Girl	High Mental Ability	426	459	419	638	1942
	Medium Mental Ability	415	562	538	494	2009
	Low Mental Ability	117	153	749	191	1210
Totals		1989	2278	2890	3348	10505

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